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ISOMETRIC EXERCISES — A MEANS OF PREVENTING MUSCULAR ATROPHY IN THE TREATMENT OF FRACTURES OF THE EXTREMITIES

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ISOMETRIC EXERCISES — A MEANS OF PREVENTING MUSCULAR ATROPHY IN THE TREATMENT OF FRACTURES OF THE EXTREMITIES[1]

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ABSTRACT. Tests using static tension of the muscles immobilized from traumas to prevent muscular atrophy were carried out. It is found that isometric tension of the muscles lasting 5 - 7 seconds used in a general complex of physical exercises is an effective means of preventing muscular atrophy.

The advisability of using therapeutic physical training as a means of /140* preventing the muscular atrophy which develops during the treatment of fractures of the extremities has been shown in numerous works. However, the extensive information accumulated in the literature regarding innervation of various parts of the support-motor apparatus (bones, joints, muscles and tendons) has not been used sufficiently in problems of functional recovery. Physiological studies in the last ten years have shown that the normal state of motoneurons, along with supraspinal influences, is determined by constant pulsation from the Golgi tendon receptors and muscular spindles. Only in /141 certain inter-relations of tendon and muscle afferentation is it possible to maintain muscular tone and perform coordinated movements.

Due to the works of R. Granit, D. Ekkl' and other authors, it has become known that muscular receptors — muscle spindles — are not autonomous,

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*Numbers in the margin indicate the pagination in the original foreign text.

independent of the central nervous system. It has been shown that these receptors have their own system of innervation. Because of this — irrespective of the dependence on the state of the entire muscle — the character of the efferent impulsation from these receptors can vary markedly. At the present time it is known that one-third of the motor nerve is composed of efferent fibers. These fibers have no motor effect as they do not end in muscular fibers, but in the so-called muscular poles of the receptors. Depending on the impulses arriving along these γ-efferents, the spindle is more or less tensed. This is connected with the greater or lesser frequency of afferent impulses to the motoneuron itself. Their interaction with inhibitory influences from the Golgi receptors also determines the excitability of the motoneurons. In addition, the works of Morucci and other authors indicate that voluntary movements also do not begin directly with the excitation of α-motoneurons, but through an earlier developing excitation of γ-motoneurons, increasing muscular tone and exciting the motoneurons of the spinal cord.

Against the background of this sparse information about the role of tendon and muscle afferentation in regulating tone and movement, the muscle and its tendons must not only be considered as the source of movement. The muscle is an important receptive organ. The correlation of impulses from muscle spindles and tendons is very important not only for its normal activity, but also for the reverse development of pathological states in the treatment of traumas of the support-motor apparatus. Depending on the character of the developing conditions, we can strive to restore the normal relationship of muscle and tendon afferentation, and thereby prevention of the formation of muscular atrophy, and to restore normal functioning of the neuro-muscular apparatus.

On the basis of what has been said, we decided to use static (approximating an isometric regime) tension of the muscles immobilized in connection with trauma as a means of also preventing the reverse development of muscular atrophy.

The idea of using static exercise is not new. This methodical procedure is recommended by all modern textbooks and manuals on therapeutic gymnastics for treating traumas of the support-motor apparatus. Some authors call this method "pulse sending", others call it the "static tension" of muscles. The majority mean by these terms rhythmic tensions and relaxations of muscles (see our work, 1965). It must be noted that, in spite of the great effectiveness of this method, atrophy still develops in immobilized muscles. This is especially pronounced in those cases of fractures where the tendon apparatus of the muscle is also traumatized (fracture of the lower third of the thigh, the kneecap, etc.). It is in this particular tendon apparatus of the muscle that the Golgi receptors are mainly concentrated. Trauma in them can, in all probability, decrease the excitability of motoneutrons to a significant degree.

Assuming that the use of rhythmic tension of muscles is "inadequate" quantitatively to maintain the proper level of excitability of the motoneurons, in this work we made an attempt to use, not rhythmic, but protracted isometric tensions of the muscles. For an objective evaluation of the suggested method, we compared the results of using protracted static tensions and the rhythmic contractions of muscles which are commonly used during the immobilization period, in patients with similar traumas of the support-motor apparatus.

The object of our observations was patients with fractures of the kneecap. In selecting this localization of trauma, we proceeded from the fact that fracture of the kneecap is accompanied by trauma of the tendon of the quadriceps muscle of the thigh; in the treatment of these patients, as a rule, atrophy of the quadriceps muscle of the thigh develops rapidly and takes a long time to eliminate. /142

A total of 50 patients were examined, ranging in age from 24 to 50 years. In the complex of physical exercises, rhythmic exercises were used in 21 patients, and protracted isometric tension of muscles in 29. Of the total number of patients examined, in nine the kneecaps were removed in connection

with the complexity of the fracture (four of these individuals formed a control group, and five were in the main group of patients). Therapeutic physical training was employed beginning with the 2^{nd} - 3^{rd} day after the operation.

We conditionally subdivided the physical exercises procedure into two periods (the first — immobilization, and the second — post-immobilization); the first was also divided into two sub-periods: a) a period of absolute immobilization, lasting an average of two to two and one-half weeks; b) a period when the plaster cast was exchanged for a removable one. The latter period lasted 30 - 35 days from the time the patient was admitted.

The basic aims of therapeutic physical training in the first period were: to improve local and general blood- and lymph-circulation and respiration; to prevent hypostatic pneumonia; to prevent atrophy of the quadriceps muscle of the thigh and contracture of the knee joint; to decrease pain; to activate reparative processes in the traumatized extremity. Therapeutic physical training also helped train "self-service" and motor skills in the patients during immobilization of the extremity. The exercise complexes of the first period were composed of exercises: a) performed by nonimmobilized extremities (bending, straightening, adduction, rests, etc.); b) performed in joints of the immobilized extremity free from immobilization and c) performed by immobilized segments of the extremity (tensing and relaxing of thigh muscles, pressure along the axis, mental reproduction of the movements of bending and straightening, real possible movements, etc.).

Each exercise was always accompanied by the correct respiration. The number of physical exercises and their dosage was determined by the clinical condition of the patient, and was usually increased in proportion to recovery. Sessions with the patients were conducted two times a day for 20 - 30 minutes. The patients also performed static exercises of the muscles 3 - 4 times or more during the day for 20 - 30 minutes on their own. The patients in the

control group performed rhythmic muscle exercises, and the patients in the main group performed prolonged static exerceses. In performing the prolonged muscular exercises, special attention was given to teaching the patients not to hold their breath during the exercise.

The main purpose of therapeutical physical training in the post-immobilization period (from the time of complete removal of plaster immobilization) was to eliminate muscular atrophy forming during the immobilization period and stiffness of the knee joint. The degree and length of isometric exercise of the thigh muscles was considerably increase in this period (Figure 1).

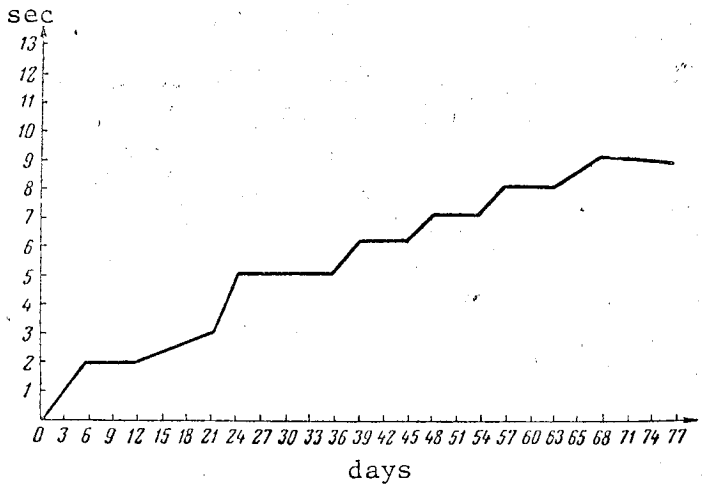

Figure 1. Average length of the state of isometric tension of the quadriceps muscle of the thigh in the treatment process.

Objective methods for /143 studying the condition of the neuro-muscular apparatus were clinical (measurement of the circumference of segments of the extremity, extent of movement in the knee joint, dynamometry, etc.) and special physiological studies: electromyography and the graphic recording of "muscular memory" (maintaining a given degree of muscle tension in time). All studies were conducted in comparison with corresponding indices of the symmetrical undamaged extremity.

Electromyograms (EMG) were recorded on an ink-writing oscillograph after preliminary intensification of biopotentials by an amplifier with a rheostat-capacity connection. Biopotentials were taken with the help of round, silver,

periodically chlorinated electrodes, 0.5 cm in diameter, attached to the skin in the region of the quadriceps muscle of the thigh with soft rubber bands. The points at which the biopotentials were taken and the distances between the electrodes were the same in all studies. "Muscular memory" was also graphically recorded on an ink-writing oscillograph. For a transmitter we constructed a special tensor-transmitter attached to the skin in the region of the muscle under study. The smallest change in the degree of muscle tension was detected by this transmitter; after intensification by a direct-current amplifier, it was transmitted to the recording system of the oscillograph.

We conducted all studies repeatedly during the treatment until complete recovery of functional mobility of the previously damaged extremity was reached. We used a number of studies (electromyography, recording of "muscular memory") beginning with the first days of treatment; a number of others (dynamometry, measurement of surrounding region, etc.) were used only from the time the plaster was removed.

In analyzing the EMG, the following patterns were revealed which are characteristic of both groups of patients. On the EMG taken from the quadriceps muscles of healthy and damaged extremities 2 - 3 days after the fracture, a marked decrease in electric activity of the muscles was noted on the damaged side (Figure 2). Subsequently, EMG indices of the muscles of the damaged extremity gradually improved; this is expressed in the increased height and frequency of the oscillations. During the entire period of immobilization, complete recovery, i.e., the beginning of equivalent indices of electric activity in the muscles of the healthy and damaged extremity, was not noted once. However, in the immobilization period, bioelectric activity of the muscles in patients in the main group was restored much quicker than in the patients in the control group. By the end of the immobilization period, in the majority of patients, it approached the corresponding indices of the healthy extremity (Figure 3).

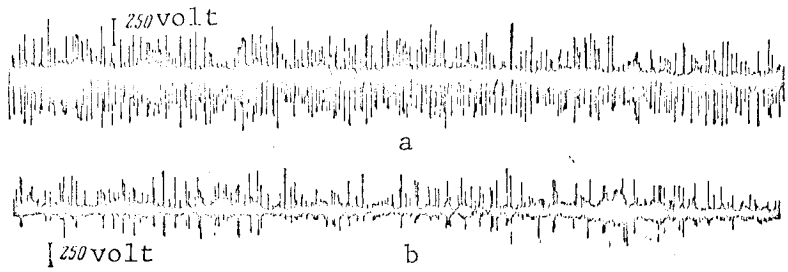

Figure 2. Electromyograms of the quadriceps muscle of the thigh on the third day after trauma

a - healthy; b - damaged extremity

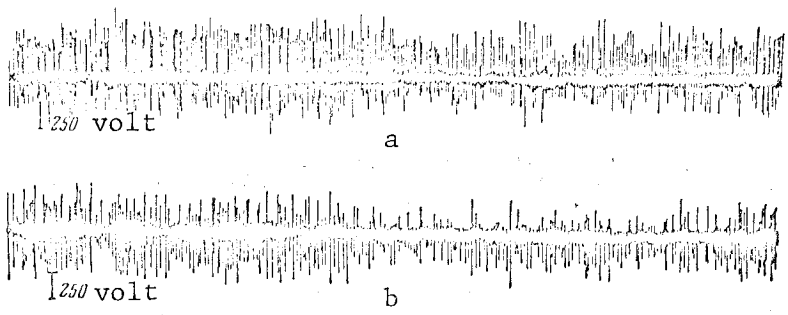

Figure 3. Electromyograms of the quadriceps muscle of the thigh in the same patient at the end of the immobilization period.

a - healthy; b - damaged extremity

After immobilization ended, bioelectric activity in the quadriceps muscle of the thigh was as a rule restored in patients in the main group after 3 - 4 weeks, and in the control group in 11 of the 21 examinees after 1 - 1/2 months. In the remaining patients of the control group the electromygraphic pattern of the damaged extremity remained low for 5 - 6 months from the time of trauma.

The results of electromygraphic studies agree with the measurement indices /144 of the circumference of the thigh. In all the examinees the circumference of

the thigh of the damaged extremity was less than on the healthy side. However, this difference was considerably less pronounced in patients of the main group. Thus, if the average decrease in the circumference of the thigh of the damaged extremity was 5.3 cm by the time immobilization ended, in comparison with the healthy extremity in patients in the control group, the corresponding index in the main group of patients was 1.9 cm. The circumference of the damaged extremity was restored in the post-immobilization period much more quickly in patients of the main group (1 - 1 1/2 months in the main group and 5 - 6 months in the control).

Impressive data were obtained in dynamometry of the quadriceps muscle of the thigh which was conducted in patients of both groups 3 - 5 weeks after immobilization ended[3]. An analysis of these data showed that in the main group of patients there was practically no difference between the indices of the healthy and the damaged extremity. The existing difference (1 - 5 kg) can be attributed to natural differences between the right and left extremity. This is corroborated by the fact that in individual cases dynamometry indices of the damaged extremity were better than the healthy.

Research, conducted to study "muscular memory", showed that by itself trauma decreases to a significant degree the ability of the neuro-muscular apparatus to maintain a given tension not only in the damaged extremity, but in the healthy one as well. Figure 4 presents a diagram of changes in muscle tension in patient N. on the third day after trauma. As seen in Figure 4, from the very beginning of the study, muscle tension was irregular in the damaged side with frequent and wide fluctuations of amplitude. There is also a similar instability — which however develops later and is less pronounced — in the indices of the quadriceps muscle of the thigh of the undamaged extremity. By the end of a week, the indices of the healthy extremity in patients of both

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(3) At this period, the patients recover the function of bending in the knee joint, which makes it possible to study the straightening function of the quadriceps muscle of the thigh.

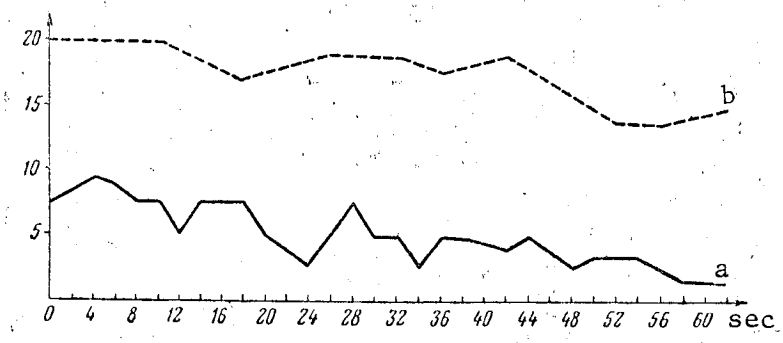

Figure 4. Diagram of fluctuations of muscle tension of patient N. on the third day after trauma

a - damged; b - healthy extremity

groups usually normalize. In the damaged extremity of patients in the basic group, the fluctuating character of muscle tension is gradually smoothed and completely evens out by the time immobilization ends. In patients of the control group, the instability of muscle tension, although it also has a tendency to level off gradually, did not however completely even out in most cases, even in 5 - 6 months of observation. /145

In conclusion, it must be emphasized that of the 29 patients in the main group, the quadriceps muscle of the thigh was maintained in a state of isometric tension in 16 of them on the average for 5 - 7 seconds, and in 13 patients for ten seconds or more. A comparison of the shifts in the neuro-muscular apparatus of patients did not reveal any advantage from using ten-second or more prolonged tension in comparison with 5 - 7 second. Therefore, the optimum length of isometric exercises of muscles in the treatment of fractures of extremities in the immobilization period must be 5 - 7 seconds.

Conclusions

1. Studies conducted on patients with fractures of the knee cap showed that this trauma is accompanied by rapidly developing atrophy of the quadriceps muscle of the thigh, which takes a long time to eliminate. The use of therapeutic physical training prevents, to a certain degree, the formation of atrophy and promotes its reverse development.

2. A comparison of the results of treating two groups of patients with similar diseases indicates that the better results of treatment, obtained in patients of the main group, is due to their use of our suggested method of prolonged isometric tension of muscles of the immobilized extremity.

3. Isometric tension of muscles, lasting 5 - 7 seconds, used in a general complex of physical exercises, is a sufficiently effective means of preventing and treating muscular atrophy. This method can be recommended for wide use in treating traumas of the support-motor apparatus.

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